



Checklist of water bugs (Hemiptera: Heteroptera: Nepomorpha, Gerromorpha) of Slovakia

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Abstract

The water bugs represent a significant component of the freshwater biota, play an important role in trophic webs, and may have considerable economic importance. Nevertheless, systematic research of this group has been underdeveloped in Slovakia (central Europe) for decades. This work presents a list of water bug species of Slovakia based on an exhaustive review of the literature (time span: 1808–2013) and on more than 14,000 individuals collected during extensive field campaigns (2010–2014) or obtained from insect collections. Fifty-six species belonging to 11 families of Heteroptera were recorded from a total of 767 sites. Seven species were recorded for the first time from Slovakia during our research. Among those, the first exact records of *Corixa panzeri* Fieber, 1848, *Sigara* (*Subsigara*) *distincta* (Fieber, 1848), *Notonecta* (*Notonecta*) *lutea* Müller, 1776, *Notonecta* (*Notonecta*) *maculata* Fabricius, 1794 and *Microvelia* (*Microvelia*) *buenoi* Drake, 1920 are provided here. Confusion concerning the records of two additional species, *Arctocoris carinata* (C. R. Sahlberg, 1819) and *Hesperocoris parallela* (Fieber, 1860) is clarified. The water bugs species inventory appears to be nearly complete (~97 %) given an asymptotic richness estimate. The occurrence of other species is discussed taking into account their habitat requirements and distribution in neighbouring countries. Recommendations for future research are provided.

Key words: Diversity, species richness, inventory, *Corixa panzeri*, *Sigara distincta*, *Notonecta lutea*, *Notonecta maculata*, *Microvelia buenoi*

Introduction

The aquatic and semi-aquatic Heteroptera (water bugs) represent a significant component of the world's aquatic insect biota. Most of the approximately 4800 known species belong to the infraorders Gerromorpha and Nepomorpha, and 623 species of these were recently catalogued in the Palaearctic Region (including China) (Polhemus *et al.* 1995; Andersen 1995; Aukema *et al.* 2013). These two infraorders differ in ecology and habitat preferences. True water bugs (Nepomorpha) are nectonic (e.g., Corixidae, Micronectidae, Naucoridae, Notonectidae, Pleidae) or benthic species (e.g., Nepidae, Aphelocheiridae), with the exception of ripicolous Ochteridae and Gelastocoridae, whereas semi-aquatic bugs (Gerromorpha) are pleustonic or settled in sub-humid terrestrial habitats (e.g., Gerridae, Hebridae, Hydrometridae, Mesoveliidae, Veliidae) (Polhemus *et al.* 1992). Water bugs inhabit a wide range of aquatic habitats, play an important role in food webs and may be of considerable economic importance (e.g., Schuh & Slater 1995; Papáček 2000, 2001). Nevertheless, in Slovakia (central Europe) systematic research of water bugs has been underdeveloped for decades and the group has received far less attention than in neighbouring countries (e.g., Poland—Jaczewski & Wróblewski 1976, 1978; Wróblewski 1980; Austria—Rabitsch 2005a; Czech Republic—Kment & Smékal 2002; Hungary—Boda *et al.* 2015).

The first evidence of water bugs from the area of Slovakia dates back to the Austro-Hungarian Empire. Besides

Bartholomaeides (1808) mentioning *Notonecta* and *Nepa* in the list of insects of Levoča District, Horváth (1870, 1884, 1899) and Brancsik (1878, 1880, 1887, 1891) pioneered the knowledge of the group. Most notably, Horváth compiled a catalogue of Heteroptera published in the series “Fauna Regni Hungariae” (Horváth 1897). Subsequent decades brought more taxonomic or faunistic investigations with the major contributions of Balthasar (1936, 1942), Tamanini (1949), Soós (1959) and Wroblewski (1960). For detailed information on the history of Heteroptera research in the territory of Slovakia see Horváth (1897) and Stehlík & Vavřínová (1991). Hoberlandt (1977) summarized published data in a checklist of 44 water bug species from Slovakia. Late 20th century freshwater research was mainly ecologically oriented and water bugs were recorded only sporadically (e.g., Bulánková *et al.* 1994, Bulánková 1995, Elexová 1998a). Unfortunately, the latest checklist of aquatic and semi-aquatic Heteroptera (Bulánková 2003) was based on only ~30% of published sources available and covers only 28 species and 2 genera without specifying species. Also, the Palaearctic catalogue of Heteroptera (Andersen 1995, Polhemus *et al.* 1995) includes information on the Slovak water bugs, but in several cases (especially in Notonectidae) the records from Slovakia are based on misinterpretation of the records from the former Czechoslovakia and in fact pertained to the Czech Republic; therefore, this catalogue also is insufficient as a checklist of Slovak water bugs. Thus, Hoberlandt’s (1977) contribution remains the most comprehensive list of water bug species from Slovakia. Works focused on water bugs are still rare and rather local or include brief information on newly recorded species (e.g., Bryja & Kment 2004, 2007; Faková 2005; Manko 2011; Kment *et al.* 2013; Reduciendo Klementová & Svitok 2014; Novikmec *et al.* 2015).

In order to fill an important gap in the knowledge of aquatic insects, we performed extensive surveys of water bug distributions in Slovakia. To do this we processed the material from museum, departmental and private collections as well as material from our own large-scale sampling conducted from 2010 to 2014. These data were supplemented by a complete literature review of all available publications with the aim to establish the first comprehensive checklist of aquatic and semi-aquatic Heteroptera of Slovakia.

Study area

Slovakia (16°50′–22°34′E, 47°44′–49°37′N) includes both mountainous and lowland landscapes, resulting in high elevational variability (94–2654 m a.s.l.). The mean annual temperature and total annual precipitation ranges from ~ 0.3 to 11.4°C and 500 to 1400 mm, respectively. However, considerable regional climatic differences exist. The Pannonian lowland, the warmest part of the area, typically has mean annual temperatures of > 9°C and relatively low total annual precipitation (< 600 mm). In contrast, mean annual temperatures in the coldest parts of the Carpathian Mountains are < 5°C and precipitation totals are > 1000 mm. The largest part of the country belongs to the Black Sea drainage area (Danube River basin), whereas the minority is drained to the Baltic Sea (Vistula River basin) (Miklós 2002). Aquatic habitats included in the study range from temporary pools through permanent ponds, ditches and small streams to rivers and lakes.

Material and methods

The study is based on a dataset compiled from three sources of information:

1) Published data. Records of occurrence of aquatic and semi-aquatic Heteroptera in Slovakia were collected in a comprehensive literature survey of all available archive sources. As a result, data from 54 articles and 5 monographic studies covering the period 1808–2013 are included in the dataset (Fig. 1). The surveyed papers are marked with asterisks (*) in the References section.

2) Museum and private collections. We studied unpublished material in seven museum collections (National Museum in Prague, Czech Republic (CZ); Moravian Museum in Brno, CZ; Natural History Museum in Bratislava, Slovakia (SK); Central Slovakia Museum in Banská Bystrica, SK; Homeland Museum Hlohovec, SK; Vihorlat Museum Humenné, SK and The Western Slovakia Museum in Trnava, SK), one departmental collection (Dept. of Biology and General Ecology, Technical University in Zvolen, SK) and eight private collections (Peter Bitušik, Eva Bulánková, Jozef Cunev, Vladimír Hemala, Peter Manko, Jozef Oboňa, Filip Rovný and Matúš Šoltís). All material was determined to the lowest possible taxonomic level using determination keys by Savage (1999), Rabitsch (2005b) and Tempelman & van Haaren (2009).

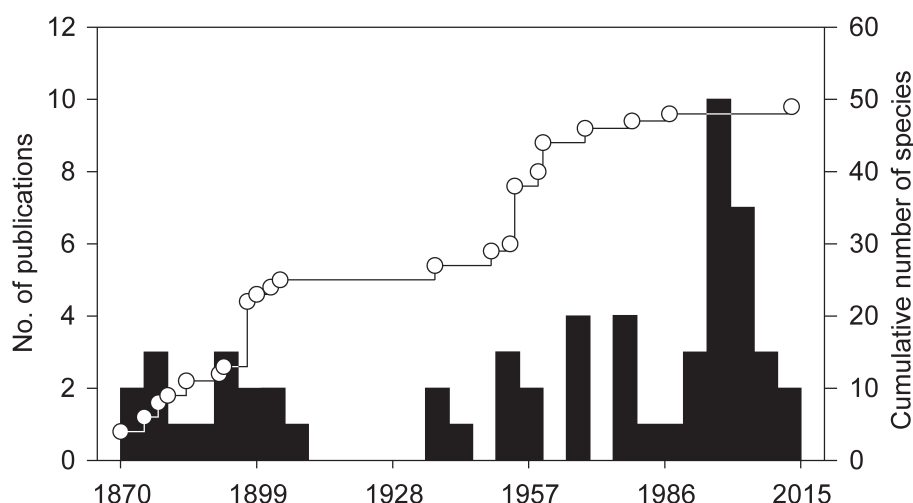


FIGURE 1. Histogram showing number of surveyed studies on water bugs in Slovakia and cumulative number of species. Note that the work of Bartholomaeides (1808) mentioning two genera (*Notonecta* and *Nepa*) is not included.

3) Extensive field survey. During 2010 to 2014, we conducted a large-scale sampling campaign across all of Slovakia. Samples were taken in various habitats using several sampling methods, including sweeping of aquatic plants above and below water, and quantitative and qualitative benthic sampling. Collected material was preserved in 70% ethanol and transferred to the laboratory for determination. Voucher material is housed in the collection of the Department of Biology and General Ecology, Technical University in Zvolen, Slovakia.

Records from those sources were included in the dataset only if the specimen was identified to the species level. Geographical coordinates and basic environmental characteristics of sampling sites were extracted from publications, unpublished records or directly measured in the field. Data from repeatedly sampled sites were pooled and presented only once.

In order to assess completeness of the species inventory, we constructed an analytical sample-based accumulation (rarefaction) curve with unconditional confidence intervals (Colwell *et al.* 2004). Consistent with the rarefaction method, we used the asymptotic richness estimator Chao2 (Chao 1987) to estimate the total number of water bug species, including those unobserved. Since detection probabilities of the species were relatively homogeneous ($CV = 0.61$) we used the bias-corrected form of the estimator (Chao 2005). The analyses were performed in EstimateS 9.1.0 (Colwell 2013) and Spade (Chao & Shen 2010).

Results

We recorded the occurrence of water bugs at 767 sites in Slovakia, with information obtained from unpublished sources (511 sites) and derived from the literature (256 sites). The sites were more or less evenly distributed in both the Pannonian and Carpathian regions (Fig. 2) and covered a range of environmental conditions; elevation: 96–2060 m, water pH: 4.6–9.7, water conductivity: 6–1725 $\mu S \cdot cm^{-1}$ (Fig. 3). The majority of the sampling sites was located in lower elevations (< 400 m) and the number of records steadily decreased toward higher elevations. However, accounting for the surface area of the elevational belts, the lowest sampling effort was encountered in mid-elevations (800–1200 m). Regarding water quality, attention has been paid chiefly to waterbodies that have relatively low conductivity ($< 800 \mu S \cdot cm^{-1}$) and are slightly alkaline ($pH = 7.5$ – 8.5).

We obtained 14,232 individuals of water bugs from unpublished sources (our extensive sampling and collections), from which we identified 52 species. Unpublished data were supplemented by a literature review of every publication related to water bugs of Slovakia, which revealed 50 species. Hence, the current checklist of water bug species includes 56 species from 11 families (Table 1). More specifically, we list 36 species of Nepomorpha (Nepidae—2, Micronectidae—5, Corixidae—21, Naucoridae—1, Aphelocheiridae—1, Notonectidae—5, Pleidae—1) and 20

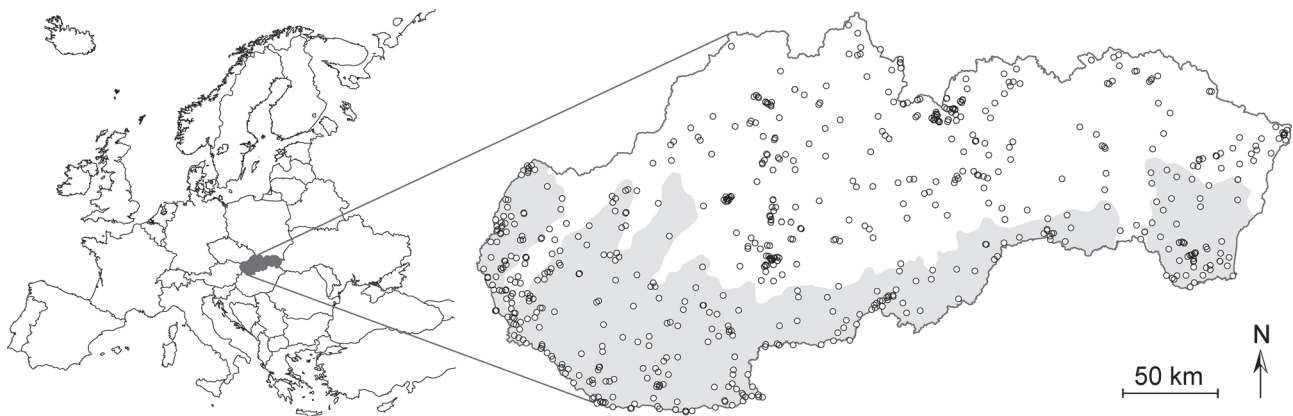


FIGURE 2. Map of Slovakia with the location of sites with recorded presence of water bugs (circles). Only sites with clearly identifiable coordinates were plotted (93% of all sites). Bioregions are distinguished by colour; Pannonian bioregion—light gray and Carpathian bioregion—white.

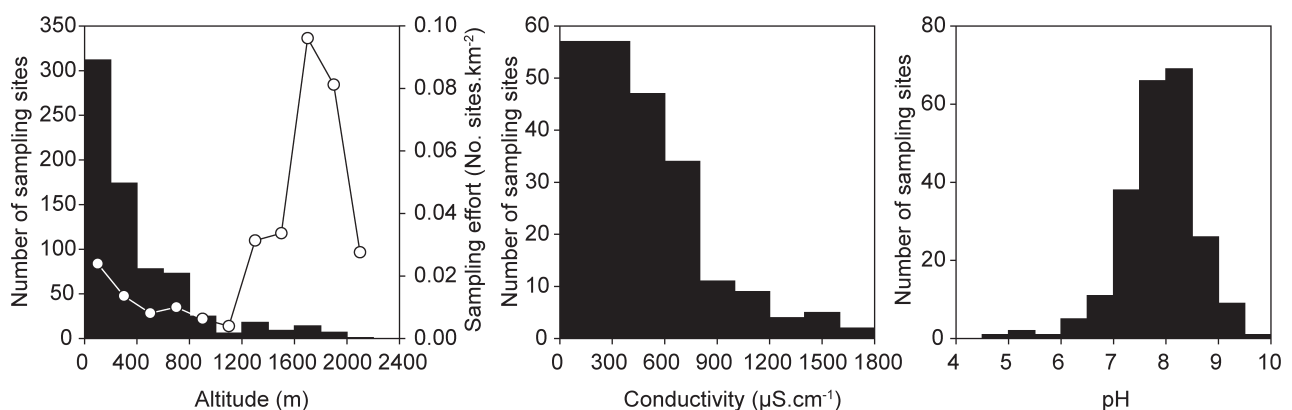


FIGURE 3. Distribution of sampling sites (histograms) according to elevation, water conductivity and pH. The sampling effort (circles) represents number of sampling sites standardized by the area of the respective elevational belt. Note that unequal number of sampling sites among plots reflects different availability of environmental data.

species of Gerromorpha (Mesoveliidae—1, Hydrometridae—2, Hebridae—2, Veliidae—5, Gerridae—10) in Slovakia. *Microvelia buenoi* Drake, 1920 is recorded for the first time from the area. *Gerris lacustris* (Linnaeus, 1758) was the most frequently occurring species, whereas *M. buenoi*, *Hesperocorixa parallela* (Fieber, 1860), *Corixa panzeri* Fieber, 1848, *Arctocorisa carinata* (C.R. Sahlberg, 1819) and *Anisops sardeus* Herrich-Schäffer, 1849 were found only at single locations (Fig. 4).

The species inventory of water bugs appears to be nearly complete as the accumulation curve reached an asymptote (Fig. 5). Expected total species richness calculated by the Chao2 estimator was 58 species (95% CI: 56–70), meaning that only two species are expected to remain undetected. Overall, the analysis suggests a high degree of inventory completeness (~97 %).

Discussion

This paper presents the first comprehensive checklist of aquatic and semi-aquatic Heteroptera of Slovakia listing 56 species from 11 families. Here, we briefly discuss new records and completeness of the species inventory and provide some suggestions for further research of aquatic Heteroptera in the area.

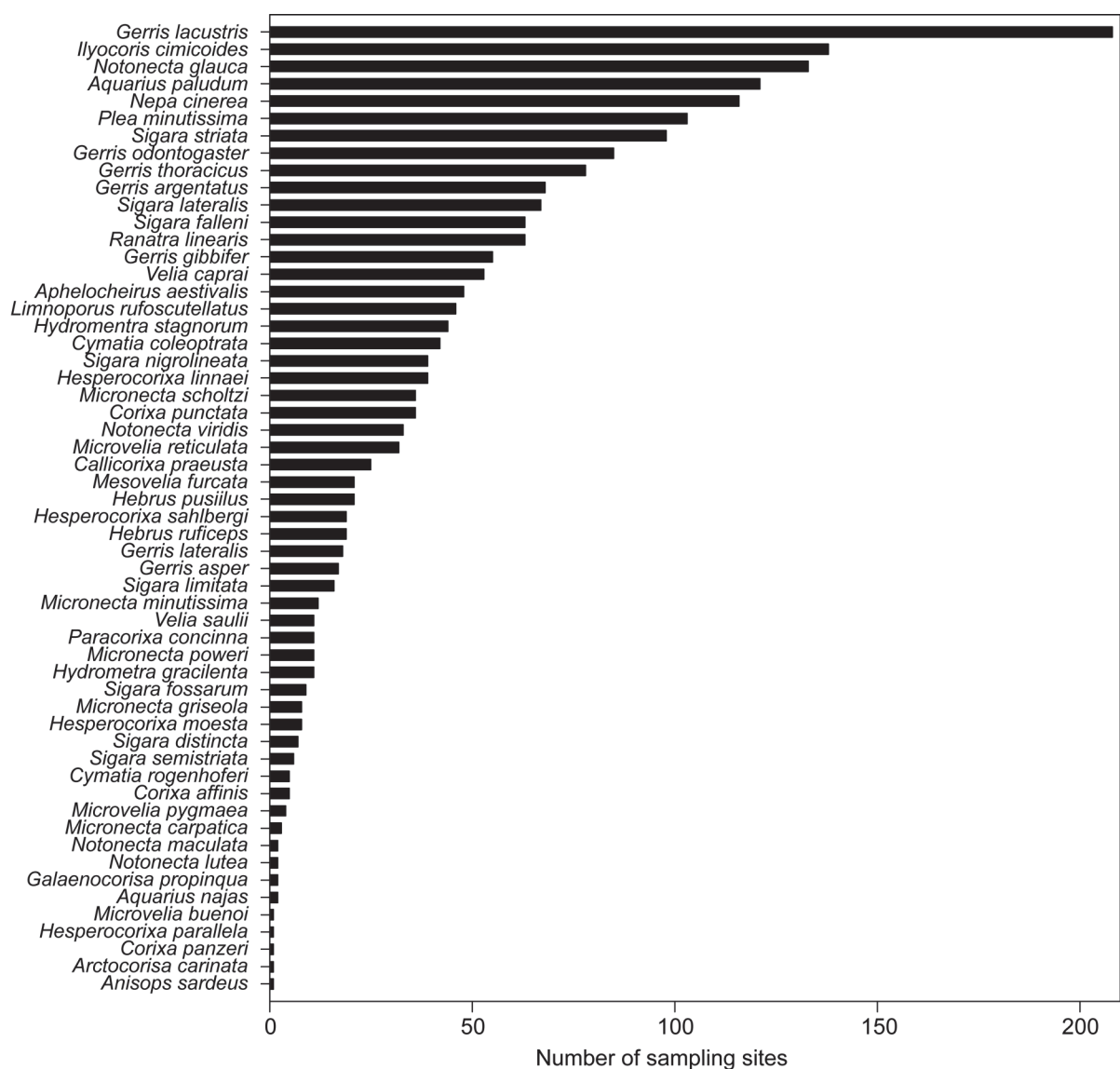


FIGURE 4. Frequency of occurrence of water bugs in Slovakia.

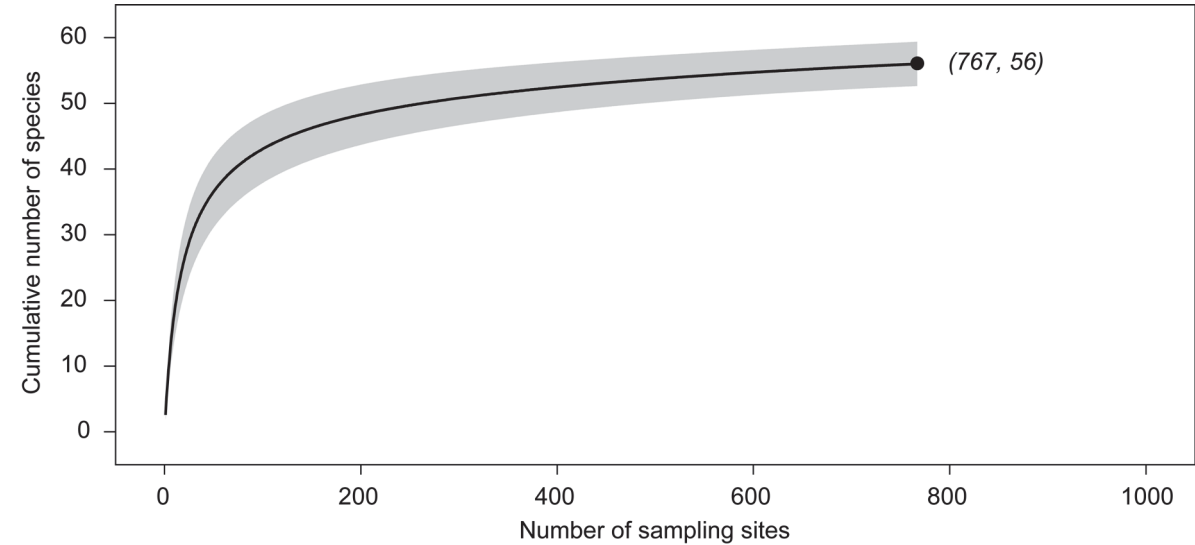


FIGURE 5. Sample-based rarefaction curve of water bug diversity in Slovakia. The numbers in parentheses are the sample size and the observed total number of species (coordinates of black circle). Gray area represents the 95% confidence envelope of the estimate.

Newly recorded species

Microvelia buenoi and *Corixa panzeri* are evidenced here for the first time from Slovakia. Five other species (*Arctocorisa carinata*, *Sigara distincta*, *Anisops sardeus*, *Notonecta lutea* and *N. maculata*) were recorded for the first time during our study. While the records of *A. sardeus* and *A. carinata* were properly published (Reduciendo Klemenová & Svitok 2014, Novikmec *et al.* 2015), the remaining three species were mentioned only in a conference abstract (Klementová *et al.* 2012) and thus their exact records are provided here. *Hesperocorixa parallela* was recorded from Slovakia by Soós (1959), but that record was overlooked by all subsequent authors (cf. Hoberlandt 1977).

Arctocorisa carinata carinata (C. R. Sahlberg, 1819)

Published record. Vysoké Tatry Mts., Vyšné Tomanovské pleso lake (49.21737°N, 19.91019°) (Novikmec *et al.* 2015).

Comment. *Arctocorisa carinata* was listed from Slovakia in the checklist by Hoberlandt (1977) but omitted in Palaearctic catalogue by Polhemus *et al.* (1995). Štys (1976) wrote: ‘... known from Czechoslovakia from Štrbské pleso in High Tatra (Szilády, 1904, as *Corisa cognata*) only’. However, this information was apparently based on incorrect translation of the Hungarian text by Szilády (1904), who only mentioned *Corisa cognata* as another species that might occur in that mountain lake. The first record of *A. carinata* in Slovakia was thus provided by Novikmec *et al.* (2015).

Corixa panzeri Fieber, 1848

Material examined. Com. Trenčín [= Trenčín District], 1 ♀, lgt. K. Brancsik, det. L. Hoberlandt 1953, revid. P. Kment & B. Reduciendo Klementová (coll. National Museum, Prague, Czech Republic).

Remarks. The species was collected in the wide environs of Trenčín city in 1874–1915 when K. Brancsik was working in that area (Kolečka 1979); information on the exact location and date of sampling are missing.

Distribution. This Palaearctic species is distributed longitudinally from Ireland to Tajikistan and latitudinally from Sweden to Algeria, Morocco and Tunisia (Jansson 1986, Polhemus *et al.* 1995, Protić 1998, Rabitsch & Zettel 2000, Dolmen 2004, Straka *et al.* 2009, Fent *et al.* 2011, Kment & Beran 2011). In Europe, *C. panzeri* is frequently found in coastal zones and becomes scarce in inland areas. In landlocked regions of Europe, records of the species are usually restricted to single specimens with the exception of the Pannonian lowlands (Straka *et al.* 2009, Kment & Beran 2011). Although the occurrence of this species in Slovakia was listed by Polhemus *et al.* (1995) and the species was collected in southern Slovakia by P. Štys (pers. comm.), there is no confirmed record so far. The first direct evidence, presented here, was obtained by our study of a single specimen collected by K. Brancsik and deposited in National Museum in Prague. *Corixa panzeri* prefers temporary, fish-less habitats with slightly saline waters, mineral-rich substrates and rich vegetation cover (e.g., Wróblewski 1980, Boix *et al.* 2001, Aukema *et al.* 2002, Straka *et al.* 2009).

Hesperocorixa parallela (Fieber, 1860)

Published record. ‘Rozsnyó: Ökörhegy [= Rožňava, Volovské vrchy Mts., Skalisko Mt., Volovec pass] (Bartkó [leg.], VII.1913 1 m*, 1280 m)’ (Soós 1959).

Comment. *Hesperocorixa parallela* is a mountain species with scattered occurrence in southern Europe, Caucasus, Transcaucasia, Turkey, Near East and Iran (Polhemus *et al.* 1995, Aukema *et al.* 2013). In Central Europe the species is confined only to the Carpathians (Slovakia, Poland, Transcarpathian Ukraine, Romania) (Soós 1959, Polhemus *et al.* 1995) where it prefers small and shallow tarns usually above 1700 m a.s.l. (Wróblewski 1980). The Slovak record by Soós (1959) was overlooked by Hoberlandt (1977) and Polhemus *et al.* (1995).

Sigara (Subsigara) distincta (Fieber, 1848)

Material examined. Kysihýbeľ [pond], 48°27'30"N, 18°56'13"E, 487 m a.s.l., 13.ix.2011, 3 ♂♂ 2 ♀♀, lgt. M. Svitok, det. B. Reduciendo Klementová (coll. Dept. of Ecology and General Biology, Technical University in Zvolen, Slovakia - DEGB); Tatra Mts., Jamské pleso [glacial lake], 49°07'58"N, 20°00'44"E, 1453 m a.s.l., 21.ix.2010, 1 ♂, lgt. M. Očadlík, det. B. Reduciendo Klementová (coll. DEGB); Nová Sedlica [pond], 49°05'02"N, 22°27'41"E, 637 m a.s.l., 25.viii.2012, 1 ♀, lgt. M. Svitok, det. B. Reduciendo Klementová (coll. DEGB); Nová Sedlica [pond], 49°05'02"N, 22°27'41"E, 637 m a.s.l., 23.iv.2013, 1 ♀, lgt. M. Svitok, det. B. Reduciendo Klementová (coll. DEGB); Lipovec [pond], 49°07'28"N, 18°55'33"E, 382 m a.s.l., 17.iv.2013, 1 ♂, lgt. M. Svitok, det. B. Reduciendo Klementová (coll. DEGB); Jastrabá [pond], 48°38'21"N, 18°57'37"E, 405 m a.s.l., 15.iv.2013, 5 ♂♂ 5 ♀♀, lgt. M. Svitok, det. B. Reduciendo Klementová (coll. DEGB); Alekšince [pond], 48°22'19"N, 17°57'14"E, 151 m a.s.l., 20.iv.2009, 1 ♀, lgt. J. Cunev, det. B. Reduciendo Klementová (coll. DEGB); Tatra Mts., Bielovodská dolina valley [unknown], 49°13'59"–49°12'40"N, 20°06'02"–20°06'19"E, 1050–1170 m a.s.l., 9.viii.1967, 1 ♀, lgt. J. L. Stehlík, det. P. Kment (coll. Moravian Museum, Brno, Czech Republic).

Remarks. In Slovakia, *S. distincta* dwells in a very wide variety of environmental conditions: elevation: 151–1453 m, pH: 5.3–9.2, conductivity: 9–580 $\mu\text{S}\cdot\text{cm}^{-1}$. The species is occasionally found in sympatry with *S. striata*.

Distribution. *Sigara distincta* is widespread in Europe, Siberia and north Africa, but is lacking in the southwestern part of Europe (Jastrey 1981, Nieser 1982). This species tolerates a wide range of habitats but prefers stagnant waters in higher elevations with low pH (5–6) and conductivity ($< 200 \mu\text{S}\cdot\text{cm}^{-1}$) (Mercken 1989, Lock *et al.* 2013).

Notonecta (Notonecta) lutea Müller, 1776

Material examined. Klin, Klinské rašelinisko [peat bog], 49°25'42"N, 19°29'46"E, 611 m a.s.l. 19.v.1993, 2 ♂♂, lgt. P. Bitušík, det. B. Reduciendo Klementová (coll. DEGB). Klin, Klinské rašelinisko [peat bog], 49°25'42"N, 19°29'46"E, 611 m a.s.l., 19.vii.1990, 1 specimen (macropterous), lgt. P. Bitušík, det. B. Reduciendo Klementová (coll. Central Slovakia Museum in Banská Bystrica, Slovakia).

Remarks. The species was found in ombrogenous peat bog pools with pH of water from 4 to 6 (Hindák 2012).

Distribution. *Notonecta lutea* is distributed in central, northern and eastern Europe, Russia and Kazakhstan (Jaczewski & Wróblewski 1978, Dioli 1994, Polhemus *et al.* 1995, Soós *et al.* 2009, Berchi 2013). This species is common in bogs overgrown with heather or *Sphagnum* spp. but can be also found in ditches or swamps with dystrophic, mixtrophic or eutrophic water (Jastrey 1981, Nieser 1982).

Notonecta (Notonecta) maculata Fabricius, 1794

Material examined. Bratislava [garden pond], 48°10'11"N, 17°06'12"E, 279 m a.s.l., 07.vii.2011, 1 ♂ 2 ♀♀, lgt. F. Rovný, det. B. Reduciendo Klementová (coll. DEGB). Podolie, Dudváh [river], 48°39'53"N, 17°46'59"E, 167 m a.s.l., 25.x.2013, 1 spec., lgt. V. Janský, det. B. Reduciendo Klementová (coll. Central Slovakia Museum in Banská Bystrica, Slovakia).

Remarks. *Notonecta maculata* was found in small (7.2 m², max. depth 0.25 m), fishless garden pond and lowland stream.

Distribution. This Palaearctic species is distributed in southern and central Europe, Great Britain, Denmark, Sweden, northern Africa, Turkey, Israel, Lebanon, Syria, Iraq, Iran and Pakistan (Jaczewski & Wróblewski 1978, Polhemus *et al.* 1995, Protić 1998, Kanyukova 2006, Soós *et al.* 2009, Fent *et al.* 2011, Berchi 2013). Kment & Baňar (2012) recorded *N. maculata* in neighbouring Moravia from one locality (Javorník, Teplica brook) just a few meters from the Slovak border. *Notonecta maculata* is found only locally and prefers small habitats (ponds and brooks) with clay substrate and a restricted amount of vegetation, usually found during early successional stages of the pools (Bosmans 1982, Lock *et al.* 2013).

Microvelia (Microvelia) buenoi Drake, 1920

Material examined. Martovce, Žitava River [alluvia], 47°51'38"N, 18°08'25"E, 106 m a.s.l., 26.ix.2014, 1 ♀ (apterous), lgt. & det. P. Kment (coll. National Museum, Prague, Czech Republic).

Remarks. The species was found in heavily vegetated river alluvia in species-rich assemblages of aquatic invertebrates including the following water bugs: *Nepa cinerea*, *Hesperocorixa linnaei*, *Sigara striata*, *Cymatia coleoptrata*, *Ilyocoris cimicoides*, *Notonecta glauca*, *Plea minutissima*, *Hydrometra gracilentia*, *Microvelia reticulata* and *Gerris argentatus*.

Distribution. This Holarctic species is distributed from the United Kingdom to northern China, Canada and northern United States. The southern boundary in Europe is delineated by France, Germany, Austria, Hungary, Romania and Ukraine; it is absent in southern Europe (Putshkov & Putshkov 1996, Rabitsch & Zettel 2000, Aukema *et al.* 2013, Kment *et al.* 2013, Berchi & Kment 2015). The species prefers shaded littoral zones of ditches, marshes and ponds, where it is particularly abundant among emergent macrophytes and submerged branches of shore vegetation (Wróblewski 1980, Aukema *et al.* 2002). Kurzatowska (1999) considered *M. buenoi* a tyrophilous species, inhabiting various dystrophic, polyhumic waters, especially in forests.

Completeness of the species inventory

The last extensive checklist of water bugs from Slovakia comprised 44 species (Hoberlandt 1977) and this number expanded to 56 species by 2015. Based on the total richness estimate, we expect that future surveys will add few additional species into the checklist (Fig. 5). The occurrence of *Arctocorisa germari germari* (Fieber, 1848), *Cymatia bonzdorffii* (C. R. Sahlberg, 1819), *Corixa dentipes* Thomson, 1869, *Hesperocorixa castanea* (Thomson, 1869), *Sigara (Microcorixa) hellensi* (C. R. Sahlberg, 1819), *S. (Subsigara) longipalis* (J. Sahlberg, 1878), *Notonecta (N.) obliqua* Thunberg, 1787, *N. (N.) meridionalis* Poisson, 1926, and *N. (N.) reuteri reuteri* Hungerford, 1928 may be reasonably expected given their environmental requirements and their presence in neighbouring countries (Wróblewski 1980, Kment & Smékal 2002, Polhemus *et al.* 2005, Rabitsch 2005a, Boda *et al.* 2015).

TABLE 1. Checklist of aquatic and semi-aquatic Heteroptera (Nepomorpha and Gerromorpha) occurring in Slovakia and references to the first records. The species list is arranged by infraorder, family, genus, (subgenus), species and subspecies, and follows standard nomenclature (Andersen 1995, Polhemus *et al.* 1995, Aukema *et al.* 2013).

Taxa	First record
Nepomorpha	
Nepidae	
<i>Nepa cinerea</i> Linnaeus, 1758	Bartholomeides (1808), Horváth (1870)
<i>Ranatra (Ranatra) linearis</i> (Linnaeus, 1758)	Brancsik (1880)
Micronectidae	
<i>Micronecta (Dichaetonecta) scholtzi</i> (Fieber, 1860)	Brtek (1954)
<i>Micronecta (Micronecta) carpatica</i> Wróblewski, 1958	Wróblewski (1960)
<i>Micronecta (Micronecta) griseola</i> Horváth, 1899	Wróblewski (1960)
<i>Micronecta (Micronecta) minutissima</i> (Linnaeus, 1758)	Wróblewski (1960)
<i>Micronecta (Micronecta) poweri poweri</i> (Douglas & Scott, 1869)	Wróblewski (1960)
Corixidae	
<i>Arctocorisa carinata carinata</i> (C.R. Sahlberg, 1819)	Klementová <i>et al.</i> (2012)
<i>Callicorixa praeusta praeusta</i> (Fieber, 1848)	Horváth (1897)
<i>Corixa affinis</i> Leach, 1817	Horváth (1987)
<i>Corixa panzeri</i> Fieber, 1848	present study
<i>Corixa punctata</i> (Illiger, 1807)	Horváth (1897), Brtek (1954)

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TABLE 1. (Continued)

Taxa	First record
<i>Cymatia coleoptrata</i> (Fabricius, 1777)	Brancsik (1891)
<i>Cymatia rogenhoferi</i> (Fieber, 1864)	Brtek (1954)
<i>Glaenocorisa propinqua</i> (Fieber, 1860)	Szilády (1904)
<i>Hesperocorixa linnaei</i> (Fieber, 1848)	Brtek (1954)
<i>Hesperocorixa moesta</i> (Fieber, 1848)	Horváth (1897)
<i>Hesperocorixa parallela</i> (Fieber, 1860)	Soós (1959)
<i>Hesperocorixa sahlbergi</i> (Fieber, 1848)	Balthasar (1937)
<i>Paracorixa concinna concinna</i> (Fieber, 1848)	Horváth (1897)
<i>Sigara (Pseudovermicorixa) nigrolineata nigrolineata</i> (Fieber, 1848)	Soós (1959)
<i>Sigara (Retrocorixa) limitata limitata</i> (Fieber, 1848)	Petrickó (1892)
<i>Sigara (Retrocorixa) semistriata</i> (Fieber, 1848)	Horváth (1897)
<i>Sigara (Sigara) striata</i> (Linnaeus, 1758)	Brtek (1954)
<i>Sigara (Subsigara) distincta</i> (Fieber, 1848)	Klementová <i>et al.</i> (2012)
<i>Sigara (Subsigara) falleni</i> (Fieber, 1848)	Brtek (1954)
<i>Sigara (Subsigara) fossarum</i> (Leach, 1817)	Vysloužil (1979)
<i>Sigara (Vermicorixa) lateralis</i> (Leach, 1817)	Brtek (1954)
Naucoridae	
<i>Ilyocoris cimicoides cimicoides</i> (Linnaeus, 1758)	Horváth (1870)
Aphelocheiridae	
<i>Aphelocheirus (Aphelocheirus) aestivalis</i> (Fabricius, 1794)	Horváth (1897)
Notonectidae	
<i>Anisops sardeus sardeus</i> Herrich-Schäffer, 1849	Klementová <i>et al.</i> (2012)
<i>Notonecta (Notonecta) glauca glauca</i> Linnaeus, 1758	Mocsáry (1875)
<i>Notonecta (Notonecta) lutea</i> Müller, 1776	Klementová <i>et al.</i> (2012)
<i>Notonecta (Notonecta) maculata</i> Fabricius, 1794	Klementová <i>et al.</i> (2012)
<i>Notonecta (Notonecta) viridis</i> Delcourt, 1909	Stehlík & Hoberlandt (1953)
Pleidae	
<i>Plea minutissima minutissima</i> Leach, 1817	Brtek (1954)
Gerromorpha	
Mesoveliidae	
<i>Mesovelia furcata</i> Mulsant & Rey, 1852	Horváth (1884)
Hydrometridae	
<i>Hydrometra gracilentia</i> Horváth, 1899	Horváth (1899)
<i>Hydrometra stagnorum</i> (Linnaeus, 1758)	Brancsik (1878)
Hebridae	
<i>Hebrus (Hebrus) pusillus pusillus</i> (Fallen, 1807)	Brancsik (1878)
<i>Hebrus (Hebrus) ruficeps</i> Thomson, 1871	Horváth (1884)
Veliidae	
<i>Microvelia (Microvelia) buenoi</i> Drake, 1920	present study
<i>Microvelia (Microvelia) reticulata</i> (Burmeister, 1835)	Horváth (1897)
<i>Microvelia (Microvelia) pygmaea</i> (Dufour, 1833)	Kment <i>et al.</i> (2013)
<i>Velia (Plesiovelia) caprai caprai</i> Tamanini, 1947	Teyrovský (1969)

.....continued on the next page

TABLE 1. (Continued)

Taxa	First record
<i>Velia (Plesiovelia) saulii</i> Tamanini, 1947	Tamanini (1949)
Gerridae	
<i>Aquarius najas</i> (De Geer, 1773)	Balthasar (1942)
<i>Aquarius paludum paludum</i> (Fabricius, 1794)	Horváth (1870)
<i>Gerris (Gerris) argentatus</i> Schummel, 1832	Horváth (1897)
<i>Gerris (Gerris) gibbifer</i> Schummel, 1832	Balthasar (1937)
<i>Gerris (Gerris) lacustris</i> (Linnaeus, 1758)	Mocsáry (1875)
<i>Gerris (Gerris) odontogaster</i> (Zetterstedt, 1828)	Ortvay (1902)
<i>Gerris (Gerris) thoracicus</i> Schummel, 1832	Horváth (1870)
<i>Gerris (Gerriselloides) asper</i> (Fieber, 1860)	Horváth (1897)
<i>Gerris (Gerriselloides) lateralis</i> Schummel, 1832	Teyrovský (1969)
<i>Limnporus rufoscutellatus</i> (Latreille, 1807)	Horváth (1897)

Arctocorisa germari germari is a Euro-Siberian species distributed from Ireland and Norway to East Siberia (Polhemus *et al.* 2005; Aukema *et al.* 2013). Among neighbouring countries, the species is known from scattered records in Austria, Czech Republic, and Poland (e.g., Wróblewski 1980, Rabitsch & Zettel 2000, Kment *et al.* 2013). This boreo-montaneous species inhabits pelagial zone of oligotrophic waters, including those with very low pH (Savage 1989, Wollmann 2000, Bonte *et al.* 2001).

Another Euro-Siberian species with occurrence expected in Slovakia is *Cymatia bonsdorffii*. This species is distributed in Europe (except for south Europe), Siberia, Russia, Kazakhstan, Mongolia, and China and it occurs in all neighbouring countries except Hungary (Polhemus *et al.* 2005). In central Europe, *C. bonsdorffii* dwells in dystrophic waterbodies with well developed vegetation, lower pH and low conductivity (Bonte *et al.* 2001, Kurzątkowska 2008).

Corixa dentipes is widespread in Europe and known in all neighbouring countries except Hungary (Polhemus *et al.* 1995, Boda *et al.* 2015). The species dwells in various habitats with shallow water and rich detritus supply (e.g., ponds, ditches), very low pH (3–5) and low conductivity ($< 500 \mu\text{S}\cdot\text{cm}^{-1}$) avoiding eutrophic waters (Wollmann 2000, Bonte *et al.* 2001). It was recorded from Trenčín environs by Brancsik (1887), but later the record was found to be based on misidentification of *Corixa punctata* (see Horváth 1897: 45).

Hesperocorixa castanea occurs through northern and western Europe, western parts of central Europe and in the Iberian Peninsula (Polhemus *et al.* 1995). The species is known from the Czech Republic (western Bohemia) and Poland and Polhemus *et al.* (1995) listed its occurrence in Slovakia with a question mark. We found several juvenile and/or female specimens of small *Hesperocorixa* in Tatra Mountains that resembles *H. castanea*. However, only adult and fully developed males can be reliably determined to the species level. Thus we tentatively identified those individuals as *H. moesta*, which are morphologically very similar species from the same lineage (Dunn 1979, Jansson 1986). *Hesperocorixa castanea* is considered a typical raised bog species with preference for shallow, acidic waters of low conductivity (van Duinen 2003, Lock *et al.* 2013, Hannigan & Kelly-Quinn 2014).

Another species that could possibly occur in Slovakia is *Sigara hellensi*. This species is sparsely distributed in the central Europe, southern Scandinavia, southern Finland and western Russia (Jansson 1986, Polhemus *et al.* 1995), and was recorded in all neighbouring countries including the boundary regions (Teyrovský 1930, Kment & Smékal 2002). *Sigara hellensi* is rheophilous species, mostly inhabiting shady places with sparse vegetation in larger streams and rivers with clean and cold water, sandy-muddy bottom and low current velocity (Karg 1966, Krajewski 1969a, Wróblewski 1980).

Sigara longipalis is a boreo-montaneous species distributed in central, north and northeast Europe and Siberia (Nieser 1982, Rabitsch & Zettel 2000, Polhemus *et al.* 2005). Among neighbouring countries, *S. longipalis* is known from the Czech Republic and Poland. The species occurs typically in unshaded ponds with clear water and sparse vegetation (Krajewski 1969b, Bonte *et al.* 2001, Rabitsch & Zettel 2000).

Polhemus *et al.* (1995) listed the presence of *Notonecta obliqua* and *N. reuteri* from Slovakia; however, no direct evidence is available and we presume that information is based on misinterpretation of the records from the

former Czechoslovakia, which pertain to Czech Republic. Both species are known in all neighbouring countries except for *N. obliqua* in Ukraine [in the Czech Republic the species is limited only to western Bohemia (Kment & Smékal 2002)]. The range of *N. reuteri* extends more toward the north, whereas *N. obliqua* occurs also in southern Europe. However, *N. obliqua* could be easily confused with the dark form of *N. meridionalis* (cf. Kanyukova 2005, Fent *et al.* 2011); thus, records of *N. obliqua* from southern Europe require careful revision. Both species prefer bogs and fens with acidic waters and low conductivity (Jaczewski & Wróblewski 1978, Dolmen 1989, Soldán *et al.* 1996, Lock *et al.* 2013).

Notonecta meridionalis occurs in southern parts of western and central Europe, southern Europe, Crimea, Morocco, Algeria, Tunisia and Turkey (Polhemus *et al.* 1995, Kment & Beran 2011). The species is known from all neighbouring countries except Poland. However, the identification of *N. meridionalis* is complicated by the variability of its hemelytral colouration and, consequently, the species is often confused with the morphologically similar species *Notonecta glauca* and *N. obliqua* (Kanyukova 2006, Soós *et al.* 2009, Fent *et al.* 2011, Berchi *et al.* 2012). *Notonecta meridionalis* occurs in a wide range of habitats (pools, oxbow lakes, springs and streams) often in sympatry with other species of *Notonecta* (Fent *et al.* 2011, Kment & Beran 2011, Berchi *et al.* 2012).

Other species present in some neighbouring countries such as *Micronecta (Dichaetonecta) pusilla* (Horváth, 1895), *Sigara (Sigara) assimilis* (Fieber, 1848), *Sigara (Subsigara) scotti* (Douglas & Scott, 1868), *Sigara (Subsigara) iactans* Jansson, 1983, or *Mesovelis termalis* Horváth, 1915 could be recorded in Slovakia at the edge of their area, but this seems improbable under the current climatic conditions. Polhemus *et al.* (1995) also asserted the occurrence of *Naucoris maculatus* from Slovakia with a question mark. This is an apparent error, because the species is regarded as Atlanto-Mediterranean and is common in the United Kingdom, France, Belgium, the Netherlands, Spain, Portugal, Italy, Anatolia and Israel (Nau & Brooke 2005).

Ongoing climate change was suggested to be the major driving force behind the recent range shifts of heteropteran species (Rabitsch 2008). Expansions of *A. sardeus* (see Reduciendo Klementová & Svitok 2014 and references therein) and *Microvelia pygmaea* (Kment *et al.* 2013) in central Europe are such examples. However, the effect of elevated temperatures is complex and can alter not only distributional ranges but also phenology, voltinism, physiology and behaviour of Heteroptera and ultimately the structure of communities (Musolin 2007). Consequently, species turnover induced by climate change should be expected.

Recommendations for future research

By extensive sampling and study of available data on water bugs from Slovakia, we have attempted to establish the first comprehensive species list. Despite the considerable effort, several species are expected to be missing in the inventory. We consider this checklist as a first step towards knowledge of the regional water bug fauna and its effective biological conservation. We suggest that future research in the area should focus on:

- 1 sampling specific habitats that were overlooked in previous research such as dystrophic waterbodies, newly created waterbodies in initial succession stages, or larger pristine streams, which may harbour previously unrecorded species (e.g. *Cymatia bonndorffii*, *Corixa dentipes*, *Hesperocorixa castanea*, *Notonecta reuteri*, *N. obliqua* and *Sigara hellensi*);
- 2 describing diversity patterns and clarifying underlying mechanisms;
- 3 identifying the major threats to diversity of water bugs; and
- 4 establishing a well-documented national red list of threatened species.

Acknowledgements

We would like to acknowledge the contribution of Peter Bitušík, Eva Bulánková, Jozef Cunev, Vladimír Hemala, Peter Manko, Jozef Oboňa, Filip Rovný and Matúš Šoltís who allowed us to study their water bug collections. We also thank Ladislav Hamerlík, Zuzana Matúšová, Miroslav Očadlík and Milan Novíkmec for their unflagging assistance with field work. Special appreciation is expressed to Rebecca Best and Ivana Svitková for reviewing an early version of the manuscript. This work was supported by the Slovak Research and Development Agency under the contract No. APVV-0059-11 and Scientific Grant Agency of the Ministry of Education, science, research and

sport of the Slovak Republic and the Slovak Academy of Sciences (VEGA 2/0081/13). The work was partly supported by the grant of the Ministry of Culture of the Czech Republic (DKRVO 2015/13, 00023272) to National Museum, Praha (Petr Kment).

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